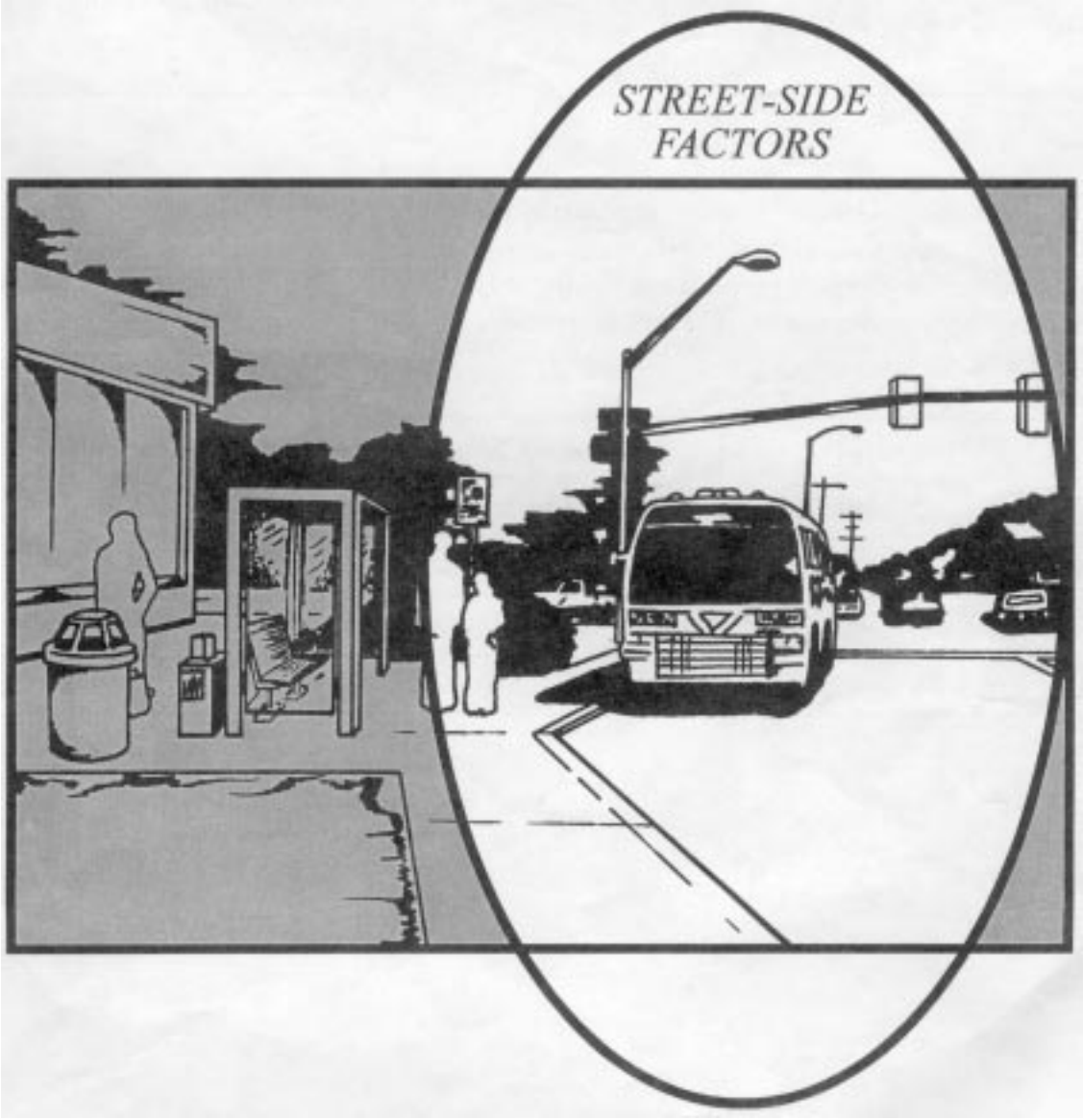
STREET-SIDE FACTORS

Chapter 3

ORGANIZATION

Street-side factors include those factors associated with the roadway that influence bus operations. This chapter begins with discussion of bus stop placement. Next is information on bus stop zone design types. Following the detailed presentation of the different types of bus stops (e.g., bus bays, nubs, etc.) is discussion of vehicle characteristics. This is followed by information on how roadway and intersection design can accommodate the unique qualities of buses. The chapter ends with information on safety and a checklist for evaluating street-side factors.



Chapter 3

STREET-SIDE FACTORS

PLACEMENT CONSIDERATIONS—Stop Spacing

Bus stop spacing has a major impact on transit vehicle and system performance. Stop spacing also affects overall travel time, and therefore, demand for transit. In general, the trade-off is between:

Close stops (every block or 1/8 to 1/4 mile), short walk distances, but more frequent stops and a longer bus trip.	Versus	Stops farther apart, longer walk distances, but more infrequent stops, higher speeds, and therefore, shorter bus trips.

The determination of bus stop spacing is primarily based on goals that are frequently subdivided by development type, such as residential area, commercial, and/or a central business district (CBD). Another generally accepted procedure is placing stops at major trip generators. The following are typical bus stop spacings used. The values represent a composite of prevailing practices.

Environment	Spacing Range	Typical Spacing
Central Core Areas of CBDs	300 to 1000 feet	600 feet
Urban Areas	500 to 1200 feet	750 feet
Suburban Areas	600 to 2500 feet	1000 feet
Rural Areas	650 to 2640 feet	1250 feet

STREET-SIDE FACTORS

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PLACEMENT CONSIDERATIONS—General Considerations

After ridership potential has been established, the most critical factors in bus stop placements are safety and avoidance of conflicts that would otherwise impede bus, car, or pedestrian flows.

In selecting a site for placement of a bus stop, the need for future passenger amenities is an important consideration (see Chapter 4). If possible, the bus stop should be located in an area where typical improvements, such as a bench or a passenger shelter, can be accommodated in the public right-of-way. The final decision on bus stop location is dependent on several safety and operating elements that require on-site evaluation. Elements to consider in bus stop placement include the following:

Safety:

- Passenger protection from passing traffic
- Access for people with disabilities
- All-weather surface to step from/to the bus
- Proximity to passenger crosswalks and curb ramps
- Proximity to major trip generators
- Convenient passenger transfers to routes with nearby stops
- Proximity of stop for the same route in the opposite direction
- Street lighting

Operating:

- Adequate curb space for the number of buses expected at the stop at one time
- Impact of the bus stop on adjacent properties
- On-street automobile parking and truck delivery zones
- Bus routing patterns (i.e., individual bus movements at an intersection)
- Directions (i.e., one-way) and widths of intersection streets
- Types of traffic signal controls (signal, stop, or yield)
- Volumes and turning movements of other traffic
- Width of sidewalks
- Pedestrian activity through intersections
- Proximity and traffic volumes of nearby driveways

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STREET-SIDE FACTORS

PLACEMENT OF BUS STOP—Far-Side, Near-Side, and Midblock Stops

Determining the proper location of bus stops involves choosing among far-side, near-side, and midblock stops (see Figure 1). Table 1 presents a comparison of the advantages and disadvantages of each bus stop type. The following factors should be considered when selecting the type of bus stop:

- Adjacent land use and activities
- Bus route (for example, is bus turning at the intersection)
- Bus signal priority (e.g., extended green suggests far side placement
- Impact on intersection operations
- Intersecting transit routes
- Intersection geometry
- Parking restrictions and requirements
- Passenger origins and destinations
- Pedestrian access, including accessibility for handicap/wheelchair patrons
- Physical roadside constraints (trees, poles, driveways, etc.)
- Potential patronage
- Presence of bus bypass lane
- Traffic control devices

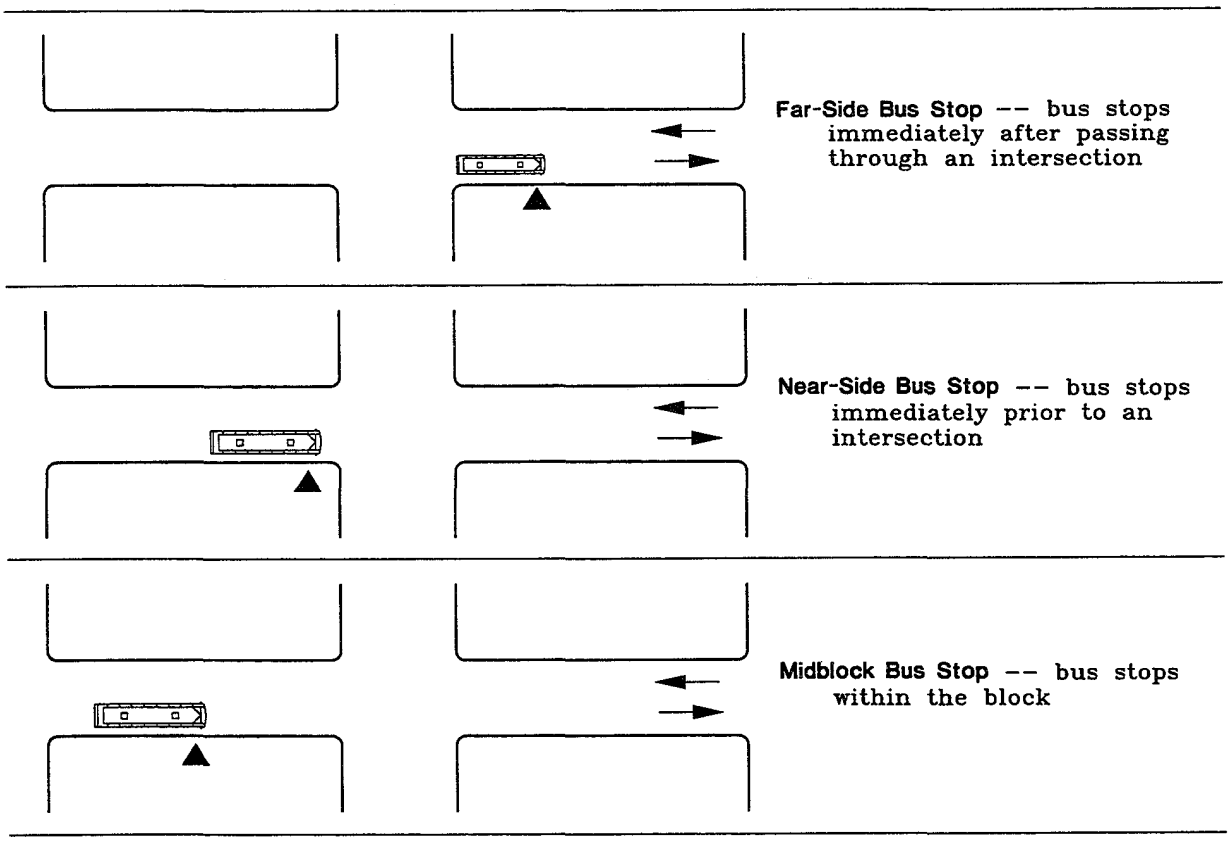

Figure 1. Example of Far-Side, Near-Side, and Midblock Stops.

Table 1. Comparative Analysis of Bus Stop Locations.

	Advantages	Disadvantages
Far-Side Stop	• Minimizes conflicts between right turning vehicles and buses • Provides additional right turn capacity by making curb lane available for traffic • Minimizes sight distance problems on approaches to intersection • Encourages pedestrians to cross behind the bus • Creates shorter deceleration distances for buses since the bus can use the intersection to decelerate • Results in bus drivers being able to take advantage of the gaps in traffic flow that are created at signalized intersections	• May result in the intersections being blocked during peak periods by stopping buses • May obscure sight distance for crossing vehicles • May increase sight distance problems for crossing pedestrians • Can cause a bus to stop far side after stopping for a red light, which interferes with both bus operations and all other traffic • May increase number of rear-end accidents since drivers do not expect buses to stop again after stopping at a red light • Could result in traffic queued into intersection when a bus is stopped in travel lane
Near-Side Stop	• Minimizes interferences when traffic is heavy on the far side of the intersection • Allows passengers to access buses closest to crosswalk • Results in the width of the intersection being available for the driver to pull away from curb • Eliminates the potential of double stopping • Allows passengers to board and alight while the bus is stopped at a red light • Provides driver with the opportunity to look for oncoming traffic, including other buses with potential passengers	• Increases conflicts with right-turning vehicles • May result in stopped buses obscuring curbside traffic control devices and crossing pedestrians • May cause sight distance to be obscured for cross vehicles stopped to the right of the bus • May block the through lane during peak period with queuing buses • Increases sight distance problems for crossing pedestrians.
Mid-block Stop	• Minimizes sight distance problems for vehicles and pedestrians • May result in passenger waiting areas experiencing less pedestrian congestion	• Requires additional distance for no-parking restrictions • Encourages patrons to cross street at midblock (jaywalking) • Increases walking distance for patrons crossing at intersections

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STREET-SIDE FACTORS

BUS STOP ZONE DESIGN TYPES—Types of Stops

Various configurations of a roadway are available to accommodate bus service at a stop. Figure 2 illustrates different street-side bus stop design while Table 2 presents their advantages and disadvantages.

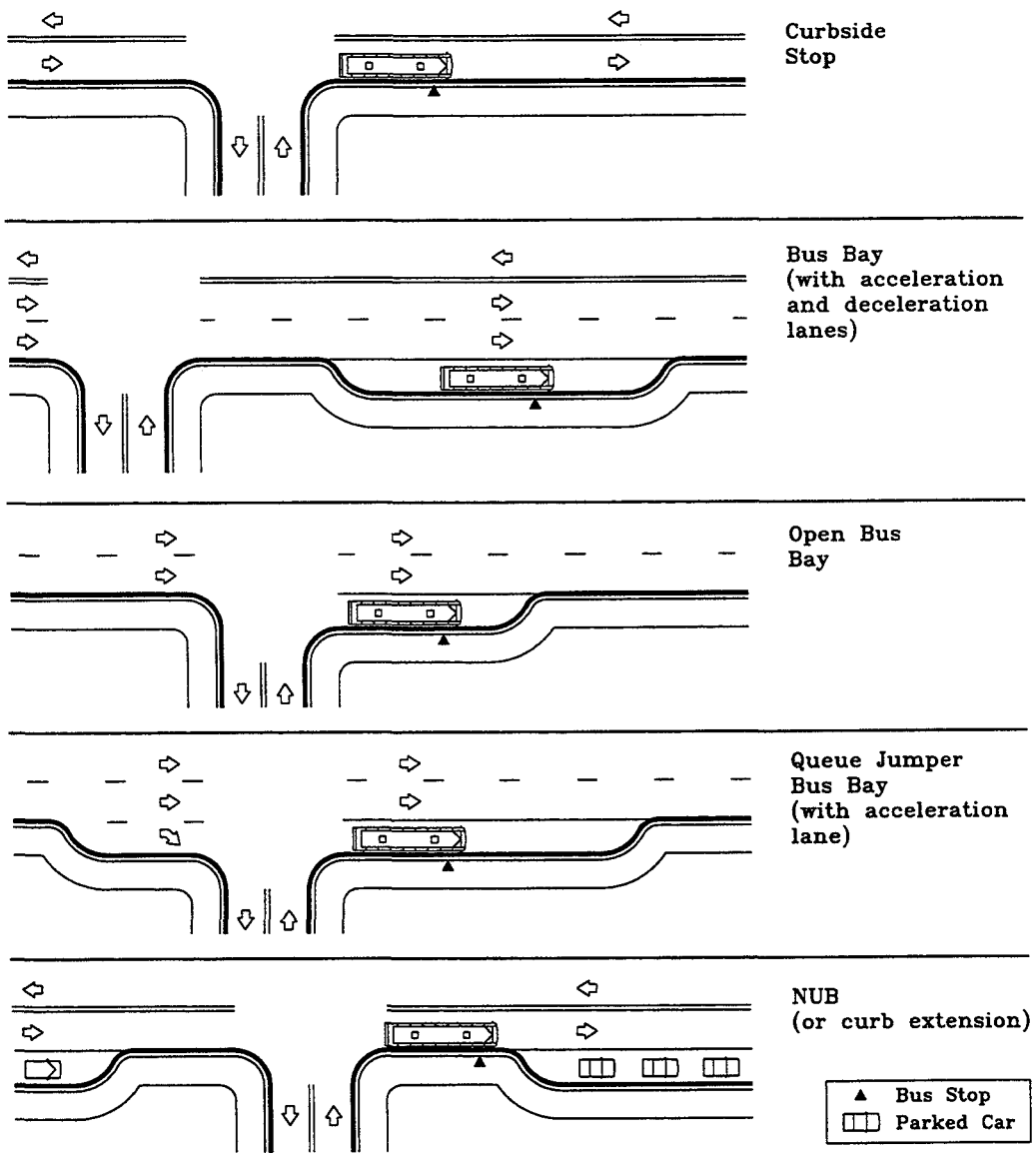

Figure 2. Street-Side Bus Stop Design.

Table 2. Comparative Analysis of Types of Stops.

Type of Stop	Advantages	Disadvantages
Curb-side	• Provides easy access for bus drivers and results in minimal delay to bus • Is simple in design and easy and inexpensive for a transit agency to install • Is easy to relocate	• Can cause traffic to queue behind stopped bus, thus causing traffic congestion • May cause drivers to make unsafe maneuvers when changing lanes in order to avoid a stopped bus
Bus Bay	• Allows patrons to board and alight out of the travel lane • Provides a protected area away from moving vehicles for both the stopped bus and the bus patrons • Minimizes delay to through traffic	• May present problems to bus drivers when attempting to re-enter traffic, especially during periods of high roadway volumes • Is expensive to install compared with curbside stops • Is difficult and expensive to relocate
Open Bus Bay	• Allows the bus to decelerate as it moves through the intersection • See Bus Bay advantages	• See Bus Bay disadvantages
Queue Jumper Bus Bay	• Allows buses to bypass queues at a signal • See Open Bus Bay advantage	• May cause delays to right-turning vehicles when a bus is at the start of the right turn lane • See Bus Bay disadvantages
Nub	• Removes fewer parking spaces for the bus stop • Decreases the walking distance (and time) for pedestrians crossing the street • Provides additional sidewalk area for bus patrons to wait • Results in minimal delay for bus	• Costs more to install compared with curbside stops • See Curb-side disadvantages

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STREET-SIDE FACTORS

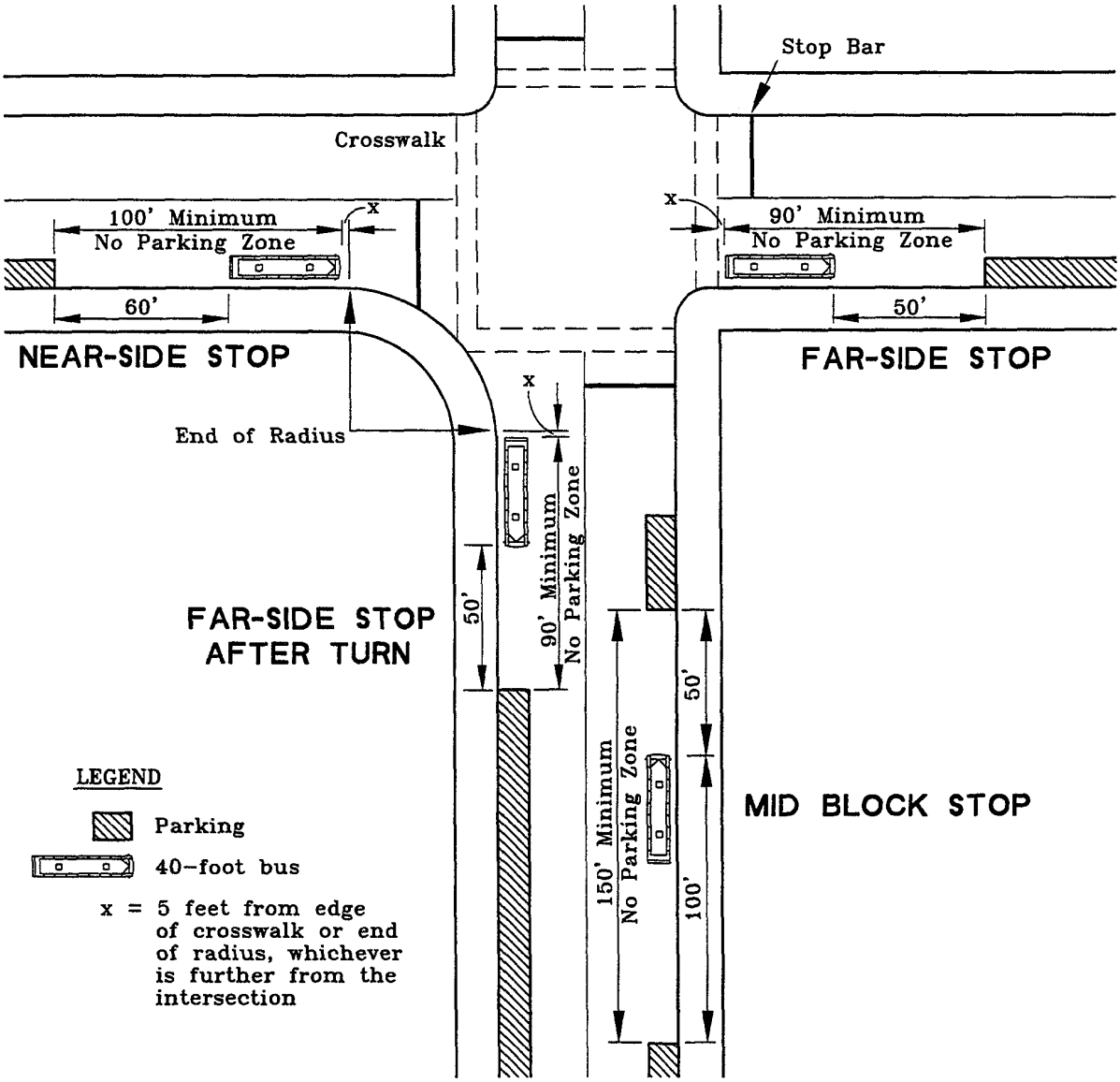
BUS STOP ZONE DESIGN TYPES—Curb-Side Bus Stop Zone Dimensions

A bus stop zone is the portion of a roadway marked or signed for use by buses when loading or unloading passengers. The lengths of bus stop zones vary among different transit agencies. In general, bus stop zones for far-side and near-side stops are a minimum of 90 and 100 feet, respectively, and midblock stops are a minimum of 150 feet. Far-side stops after a turn typically have a minimum 90-foot zone, however, a longer zone will result in greater ease for a bus driver to position the bus. Bus stop zones are increased by 20 feet for articulated buses. Representative dimensions for bus stop zones are illustrated in Figure 3.

More than one bus may be at a stop at a given time. The number of bus-loading positions required at a given location depends on 1) the rate of bus arrivals and 2) passenger service time at the stop. Table 3 presents suggested bus stop capacity requirements based on a range of bus flow rates and passenger service times. For example, if the service time at a stop is 30 seconds and there are 60 buses expected in the peak hour, two bus loading positions are needed. The arrival rate is based on a Poisson (random) arrival rate and a 5 percent chance the bus zone capacity will be exceeded.

Table 3. Recommended Bus Stop Bay Requirements.

Peak-Hour Bus Flow	Capacity Required (Bays) When Service Time at Stop Is				
	10 Seconds	20 Seconds	30 Seconds	40 Seconds	60 Seconds
15	1	1	1	1	1
30	1	1	1	1	2
45	1	1	2	2	2
60	1	1	2	2	3
75	1	2	2	3	3
90	1	2	2	3	4
105	1	2	3	3	4
120	1	2	3	3	5
150	2	3	3	4	5
180	2	3	4	5	6



Notes:

1) Add 20 feet to bus stop zones for an articulated bus.
2) Increase bus stop zone by 50 feet for each additional standard 40-foot bus or 70 feet for each additional 60-foot articulated bus expected to be at the stop simultaneously. See Table 3 for the suggested bus stop capacity requirements based on a range of bus flow rates and passenger service times.

Figure 3. Typical Dimensions for On-Street Bus Stops.

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STREET-SIDE FACTORS

BUS STOP ZONE DESIGN TYPES—Bus Bay

A bus bay (or turnout) is a specially constructed area separated from the travel lanes and off the normal section of a roadway that provides for the pick up and discharge of passengers (see Figure 4). This design allows through traffic to flow freely without the obstruction of stopped buses. Bus bays are provided primarily on high-volume or high-speed roadways, such as suburban arterial roads. Additionally, bus bays are frequently constructed in heavily congested downtown and shopping areas where large numbers of passengers may board and alight.

Figure 4. Example of a Bus Bay.

Bus bays should be considered at a location when the following factors are present:

- Traffic in the curb lane exceeds 250 vehicles during the peak hour,
- Traffic speed is greater than 40 mph,
- Bus volumes are 10 or more per peak hour on the roadway,
- Passenger volumes exceed 20 to 40 boardings an hour,
- Average peak-period dwell time exceeds 30 seconds per bus,
- Buses are expected to layover at the end of a trip,
- Potential for auto/bus conflicts warrants separation of transit and passenger vehicles,
- History of repeated traffic and/or pedestrian accidents at stop location,
- Right-of-way width is adequate to construct the bay without adversely affecting sidewalk pedestrian movement,
- Sight distances (i.e., hills, curves) prevent traffic from stopping safely behind a stopped bus,
- A right-turn lane is used by buses as a queue jumper lane,
- Appropriate bus signal priority treatment exists at an intersection,
- Bus parking in the curb lane is prohibited, and
- Improvements, such as widening, are planned for a major roadway. (This provides the opportunity to include the bus bay as part of the reconstruction, resulting in a better-designed and less-costly bus bay.)

Evidence shows that bus drivers will not use a bus bay when traffic volumes exceed 1000 vehicles per hour per lane. Drivers explain that the heavy volumes make it extremely difficult to maneuver a bus out of a midblock or near-side bay, and that the bus must wait an unacceptable period of time to re-enter the travel lane. Consideration should be given to these concerns when contemplating the design of a bay on a high-volume road. Using acceleration lanes, signal priority, or far-side (versus near-side or midblock) placements are potential solutions.

BUS STOP ZONE DESIGN TYPES—Bus Bay Dimensions

The total length of the bus bay should allow room for an entrance taper, a deceleration lane, a stopping area, an acceleration lane, and an exit taper (see Figure 5). However, the common practice is to accept deceleration and acceleration in the through lanes and only build the tapers and the stopping area. Providing separate deceleration and acceleration lanes is desirable on suburban arterial roads and should be incorporated in the design wherever feasible.

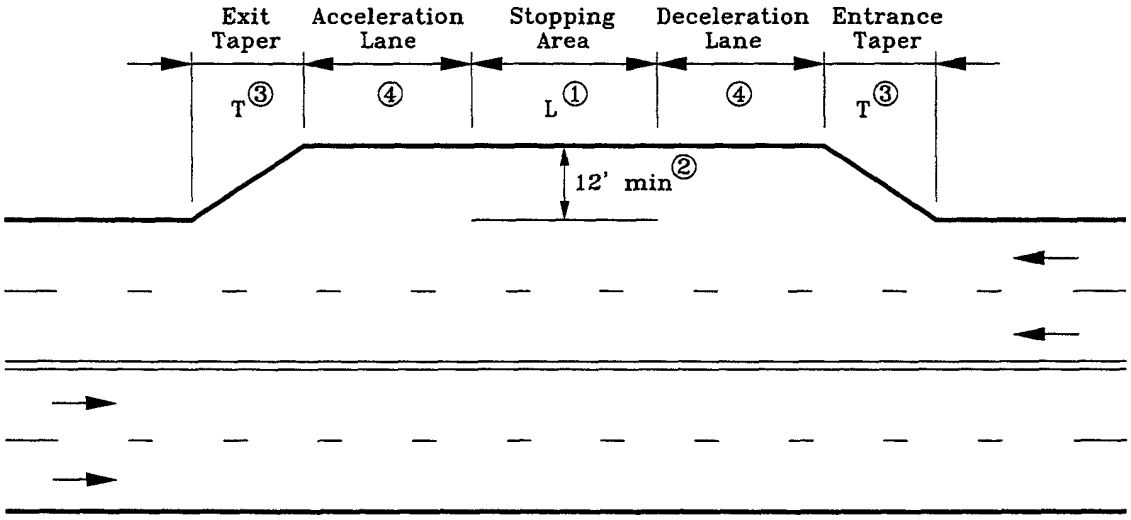
An acceleration lane in a bay design allows a bus to obtain a speed that is within an acceptable range of the through traffic speed and more comfortably merge with the through traffic. The presence of a deceleration lane enables buses to decelerate without inhibiting through traffic. Typical bus bay dimensions (minimum and recommended) are shown in Figure 5. Where bike lanes are provided, a bus bay should include a marked through lane to guide bicyclists along the outside of the bus bay.

Following are some guidelines on where to locate bus bays (e.g., far side or near side):

- Far-side intersection placement is desirable (may vary with site conditions). Bus bays should be placed at signal-controlled intersections so that the signal can create gaps in traffic.

- Near-side bays should be avoided because of conflicts with right-turning vehicles, delays to transit service as buses attempt to re-enter the travel lane, and obstruction of traffic control devices and pedestrian activity.

- Midblock bus bay locations are not desirable unless associated with key pedestrian access to major transit-oriented activity centers.



Notes:

1) Stopping area length consists of 50 feet for each standard 40-foot bus and 70 feet for each 60-foot articulated bus expected to be at the stop simultaneously. See Table 3 for the suggested bus stop capacity requirements based on a range of bus flow rates and passenger service times.
2) Bus bay width is desirably 12 feet. For traffic speeds under 30 mph, a 10-foot minimum bay width is acceptable. These dimensions do not include gutter width.
3) Suggested taper lengths are listed in table below. Desirable taper length is equal to the major road through speed multiplied by the width of the turnout bay. A taper of 5:1 is a desirable minimum for an entrance taper to an arterial street bus bay while the merging or re-entry taper should not be sharper than 3:1.
4) Minimum design for a busy bay does not include acceleration or deceleration lanes. Recommended acceleration and deceleration lengths are listed in the table below.

Through Speed (mph)	Entering Speed[a] (mph)	Length of Acceleration Lane (Feet)	Length of Deceleration Lane[b] (Feet)	Length of Taper (Feet)
35	25	250	184	170
40	30	400	265	190
45	35	700	360	210
50	40	975	470	230
55	45	1400	595	250
60	50	1900	735	270

[a] Bus speed at end of taper, desirable for buses to be within 10 mph of travel lane vehicle speed at the end of the taper.
[b] Based on 2.5 mph/sec deceleration rate.

Figure 5. Typical Bus Bay Dimensions.

STREET-SIDE FACTORS

BUS STOP ZONE DESIGN TYPES—Open Bus Bay

The open bus bay design is a variation of the bus bay design. In an open bus bay design, the bay is open to the upstream intersection (see Figure 6 for an example). The bus driver has the pavement width of the upstream cross street available to decelerate and to move the bus from the travel lane into the bay. Advantages of this design include allowing the bus to move efficiently into the bay as well as allowing the bus to stop out of the flow of traffic. Re-entry difficulties are not eliminated; however, they are no more difficult than with the typical bus bay design. A disadvantage for pedestrians is that the pedestrian crossing distance at an intersection increases with an open bus bay design because the intersection width has been increased by the width of the bay.

Figure 6. Bus Approaching an Open Bus Bay.

Another alternative to the bus bay design is a partial open bus bay (or a partial sidewalk extension). This alternative allows buses to use the intersection approach in entering the bay and provides a partial sidewalk extension to reduce pedestrian street-crossing distance. It also prevents right-turning vehicles from using the bus bay for acceleration movements. Figure 7 illustrates the design for a partial open bus bay.

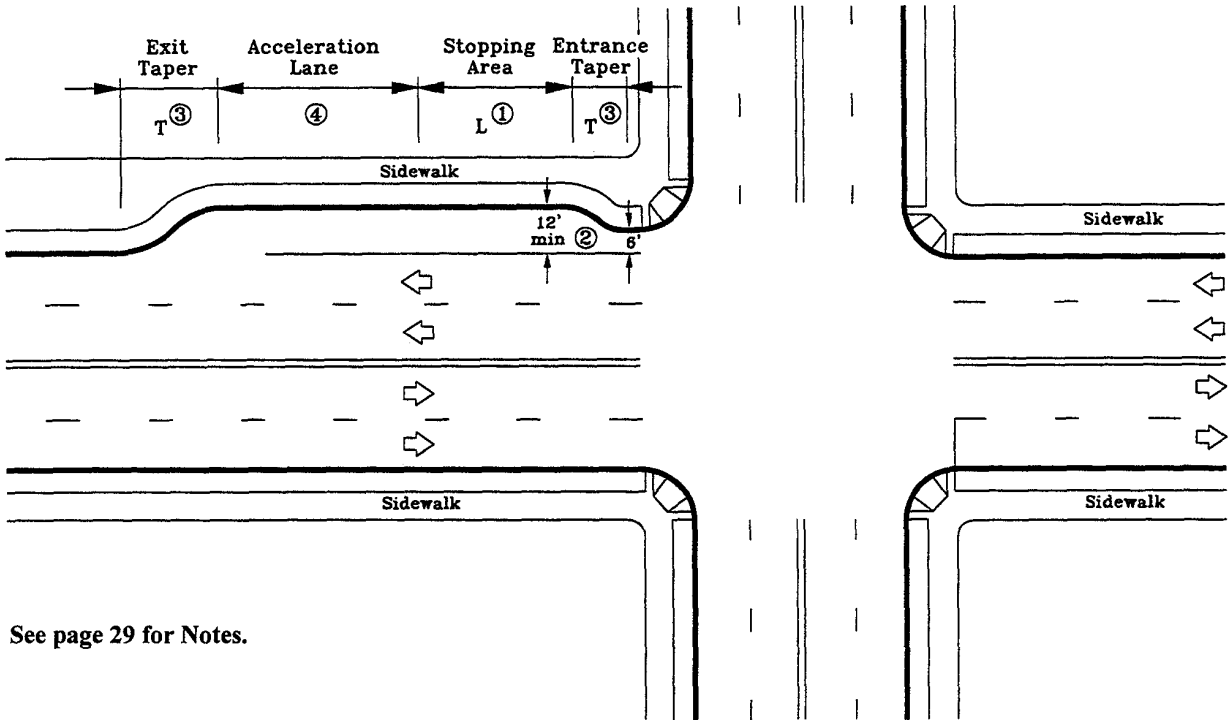


Figure 7. Partial Open Bus Bay.

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BUS STOP ZONE DESIGN TYPES—Queue Jumper Bus Bay

Queue jumper bus bays provide priority treatment for buses along arterial streets by allowing buses to bypass traffic queued at congested intersections. These bus stops consist of a near-side, right-turn lane and a far-side open bus bay. Buses are allowed to use the right-turn lane to bypass traffic congestion and proceed through the intersection. The right-turn lane could be signed "Right Turns Only—Buses Excepted." Queue jumpers provide the double benefit of removing stopped buses from the traffic stream (to benefit general traffic operations) and guiding moving buses through congested intersections (to benefit bus operations). Figure 8 is a photograph of a queue jumper bus bay while Figure 9 illustrates the layout for a queue jumper bus bay.

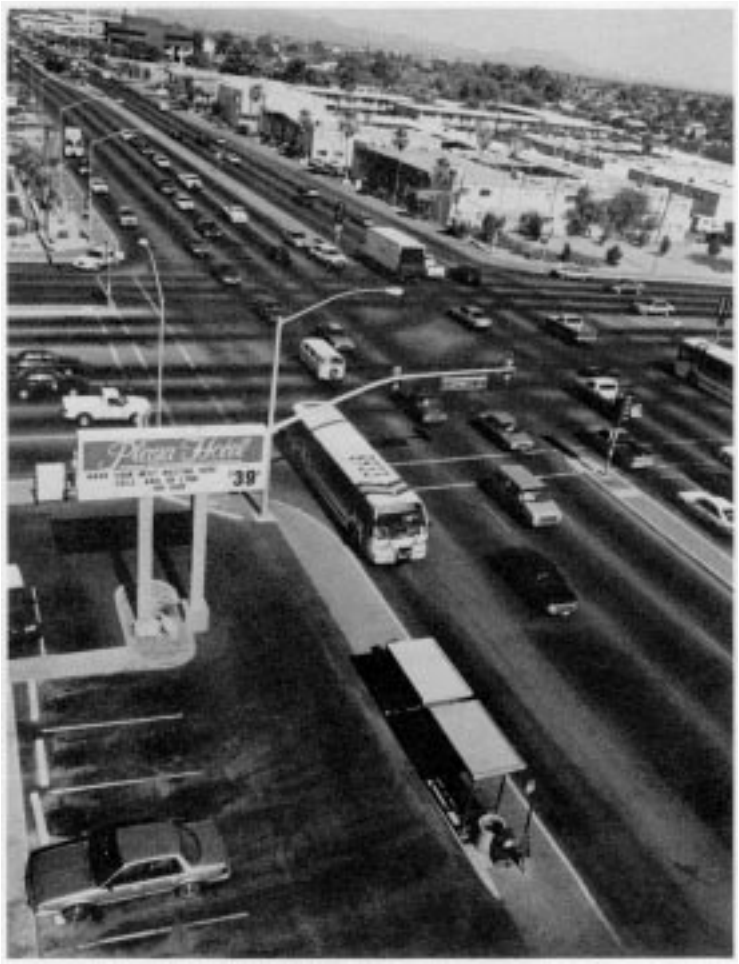
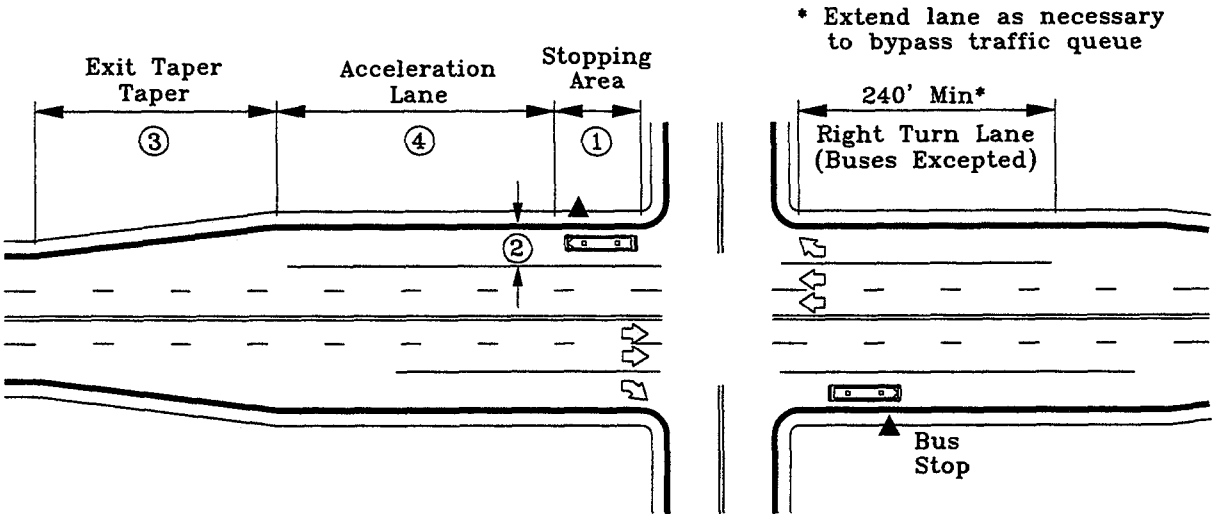


Figure 8. Example of a Queue Jumper Bus Bay.

According to the transit agencies that use queue jumper bus bays, these bays should be considered at arterial street intersections when the following factors are present:

- High-frequency bus routes have an average headway of 15 minutes or less;
- Traffic volumes exceed 250 vehicles per hour in the curb lane during the peak hour;
- The intersection operates at a level of service "D" or worse (see the Transportation Research Board's *Highway Capacity Manual* for techniques on evaluating the operations at an intersection); and
- Land acquisitions are feasible and costs are affordable.

An exclusive bus lane, in addition to the right-turn lane, should be considered when right-turn volumes exceed 400 vehicles per hour during the peak hour.



Notes for Comments 1, 2, 3, and 4 are on page 29.

Figure 9. Queue Jumper Bus Bay Layout.

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STREET-SIDE FACTORS

BUS STOP ZONE DESIGN TYPES—Nub

Nubs are a section of sidewalk that extend from the curb of a parking lane to the edge of the through lane (see Figure 10). Nubs have been used as traffic-calming techniques and as bus stops. When used as a bus stop, the buses stop in the traffic lane instead of weaving into the bus stop that is located in the parking lane—therefore, they operate similarly to curb-side bus stops. Nubs offer additional area for patrons to walk and wait for a bus and provide space for bus patron amenities, such as shelters and benches. Other names used for nubs include "curb extensions" and "bus bulbs."

Nubs reduce pedestrian crossing distances, create additional parking (compared with typical bus zones), and mitigate traffic conflicts between autos and buses merging back into the traffic stream. Nubs should be designed to allow for an adequate turning radius for right-turn vehicles. Figure 11 is a schematic of a typical bus stop nub design.

Nubs should be considered at sites with the following characteristics:

- High pedestrian activity,
- Crowded sidewalks,
- Reduced pedestrian crossing distances, and
- Bus stops in travel lanes.

Figure 10. Example of a Nub.

Nubs have particular application along streets with lower traffic speeds and/or low traffic volumes where it would be acceptable to stop buses in the travel lane. Collector streets in neighborhoods and designated pedestrian districts are good candidates for this type of bus stop. Nubs should be designed to accommodate vehicle turning movements to and from side streets.

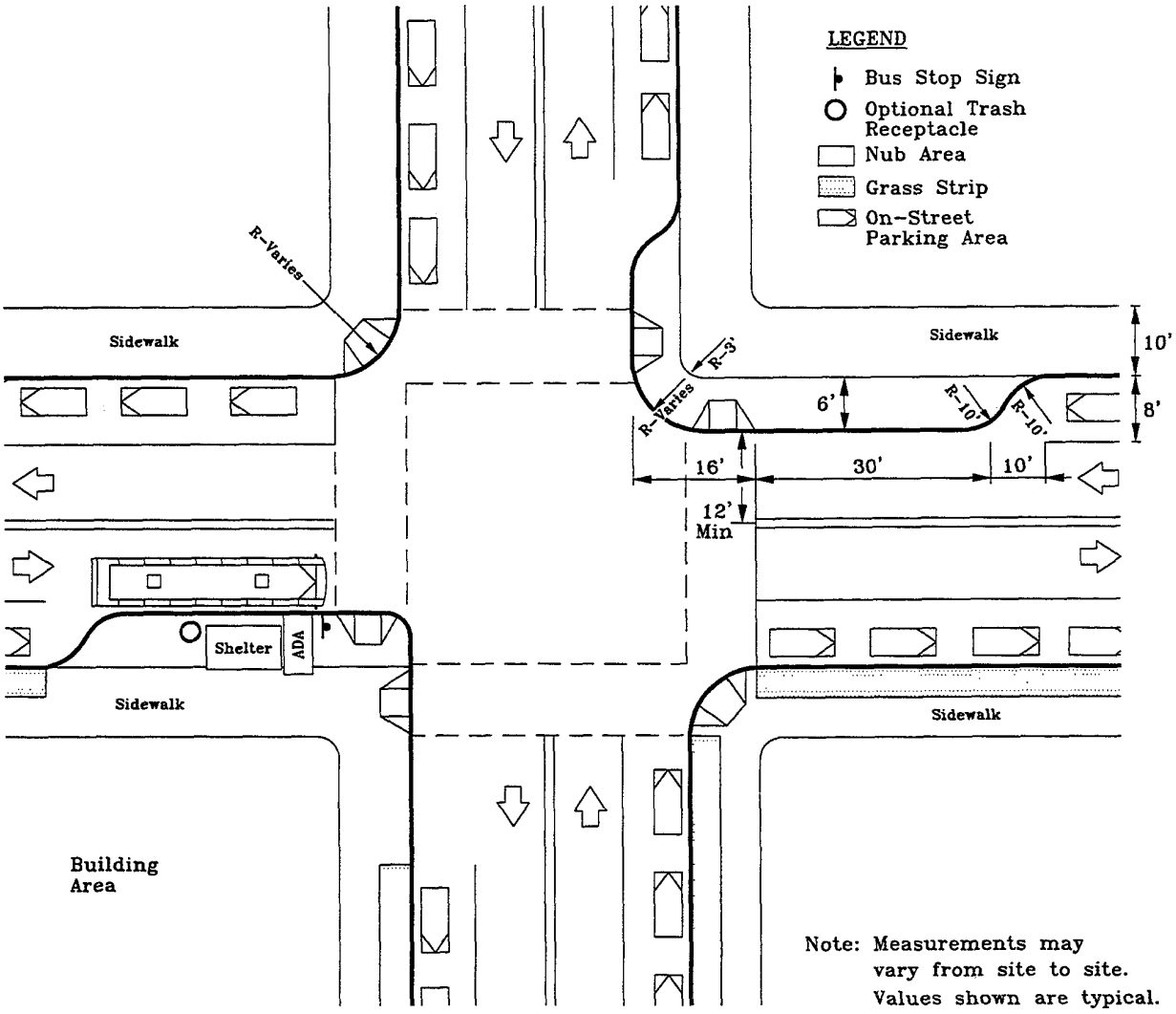

Figure 11. Typical Dimensions for a Nub.

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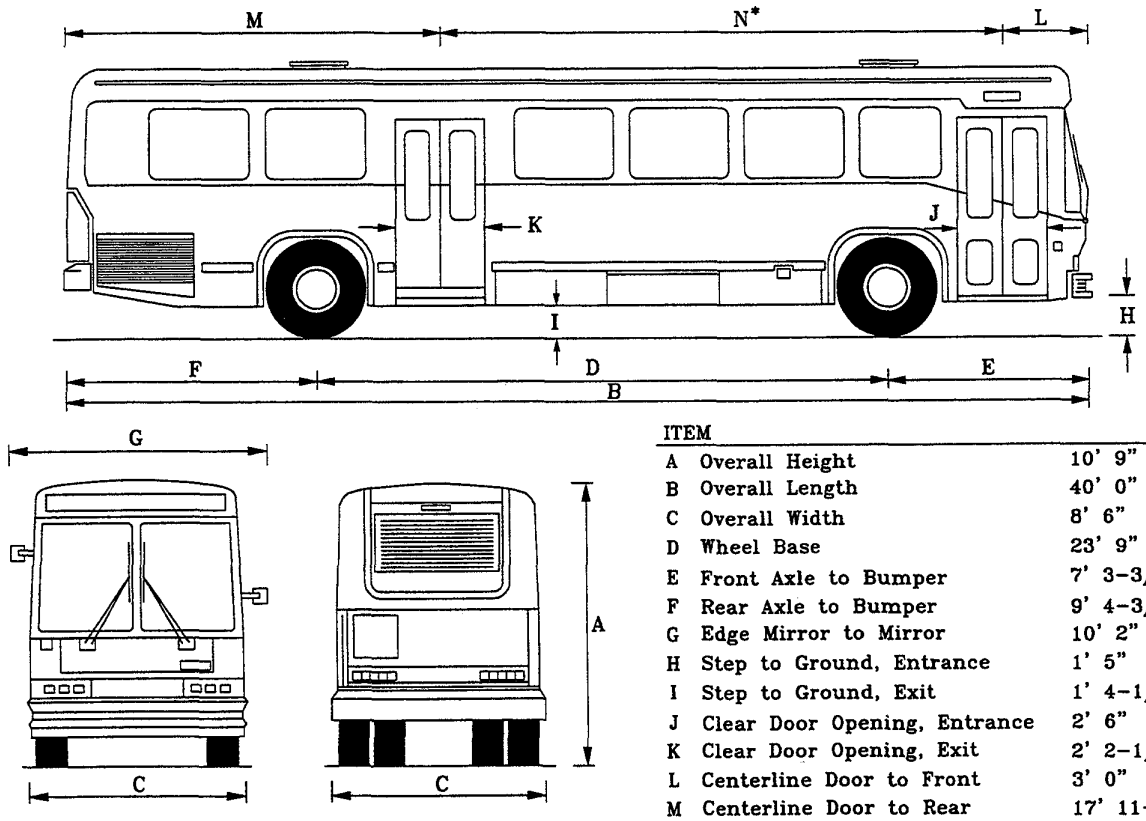
STREET-SIDE FACTORS

VEHICLE CHARACTERISTICS—Vehicle Types and Dimensions

In the design of facilities for buses, it is important to define a design vehicle that represents a compilation of critical dimensions from those vehicles currently in operation. These dimensions are used when designing roadway features. For example, the weight of the expected vehicle is important to pavement design. The following two basic bus types are commonly used by transit service providers: 1) 40-foot "standard" bus; and 2) 60-foot articulated bus.



ITEM		
A	Overall Height	10' 9"
B	Overall Length	40' 0"
C	Overall Width	8' 6"
D	Wheel Base	23' 9"
E	Front Axle to Bumper	7' 3-3/4"
F	Rear Axle to Bumper	9' 4-3/4"
G	Edge Mirror to Mirror	10' 2"
H	Step to Ground, Entrance	1' 5"
I	Step to Ground, Exit	1' 4-1/2"
J	Clear Door Opening, Entrance	2' 6"
K	Clear Door Opening, Exit	2' 2-1/2"
L	Centerline Door to Front	3' 0"
M	Centerline Door to Rear	17' 11-1/4"
N	Centerline Door to Door	19' 8"

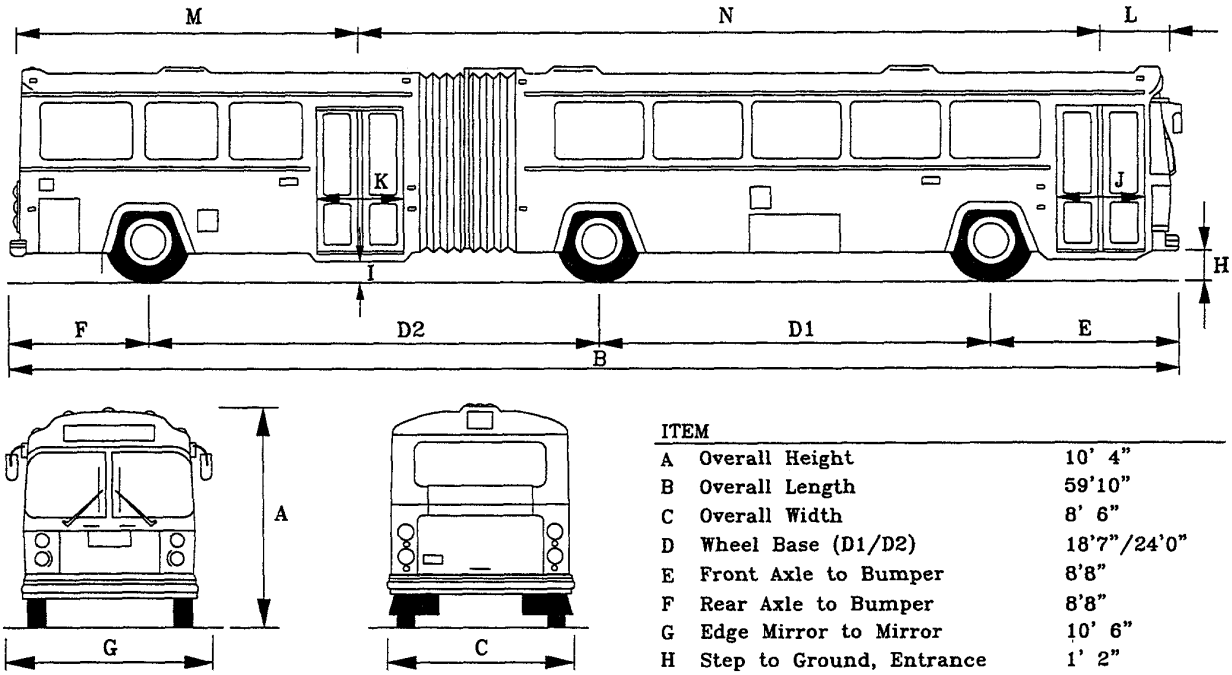
NET/GROSS VEHICLE WEIGHT **	
Front Axle	7,420/11,980
Rear Axle	18,060/24,660
Seating Capacity	51
Standing Capacity	25

NOTES

* Varies for different types of 40' buses
** Net Weight is "Road Ready" Without Passengers
Gross Includes Passengers

Figure 12. Typical Dimensions for 40-Foot Bus.

The standard 40-foot bus and the 60-foot articulated bus are generally the largest buses in a transit fleet and represent the most common designs. (Currently, manufacturers are also producing 30- and 35-foot buses.) Key roadway design features, such as lane and shoulder widths, lateral and vertical clearances, vehicle storage dimensions, and minimum turning radii are typically based on the standard 40-foot bus. The articulated bus, while longer, has a "hinge" near the center of the vehicle that allows maneuverability comparable to the 40-foot bus. Figures 12 and 13 show the dimensions for a 40-foot and 60-foot bus, respectively.



ITEM		
A	Overall Height	10' 4"
B	Overall Length	59'10"
C	Overall Width	8' 6"
D	Wheel Base (D1/D2)	18'7"/24'0"
E	Front Axle to Bumper	8'8"
F	Rear Axle to Bumper	8'8"
G	Edge Mirror to Mirror	10' 6"
H	Step to Ground, Entrance	1' 2"
I	Step to Ground, Exit	1' 2"
J	Clear Door Opening, Entrance	3' 8"
K	Clear Door Opening, Exit	3' 6"
L	Centerline Door to Front	3' 6"
M	Centerline Door to Rear	21'4"
N	Centerline Door to Door	35'0"

NET/GROSS VEHICLE WEIGHT *	
Front Axle	11,800/16,420
Rear Axle	12,130/16,420
Center Axle	14,970/24,250
MAXIMUN BEND ANGLE	
Horizontal	± 36 deg
Vertical	± 11 deg
Seating Capacity	70

* Net Weight is "Road Ready" Without Passengers
Gross Includes Passengers

Figure 13. Typical Dimensions for 60-Foot Articulated Bus.

STREET-SIDE FACTORS

VEHICLE CHARACTERISTICS—Turning Radium Template

Design templates for minimum turning paths for single-unit (40-foot) and articulated (60-foot) buses are shown in Figures 14 and 15, respectively. The templates are usable for either left turn or right turn designs depending on how the template is oriented (i.e., either face-up for right turn design or face-down for left turn design).

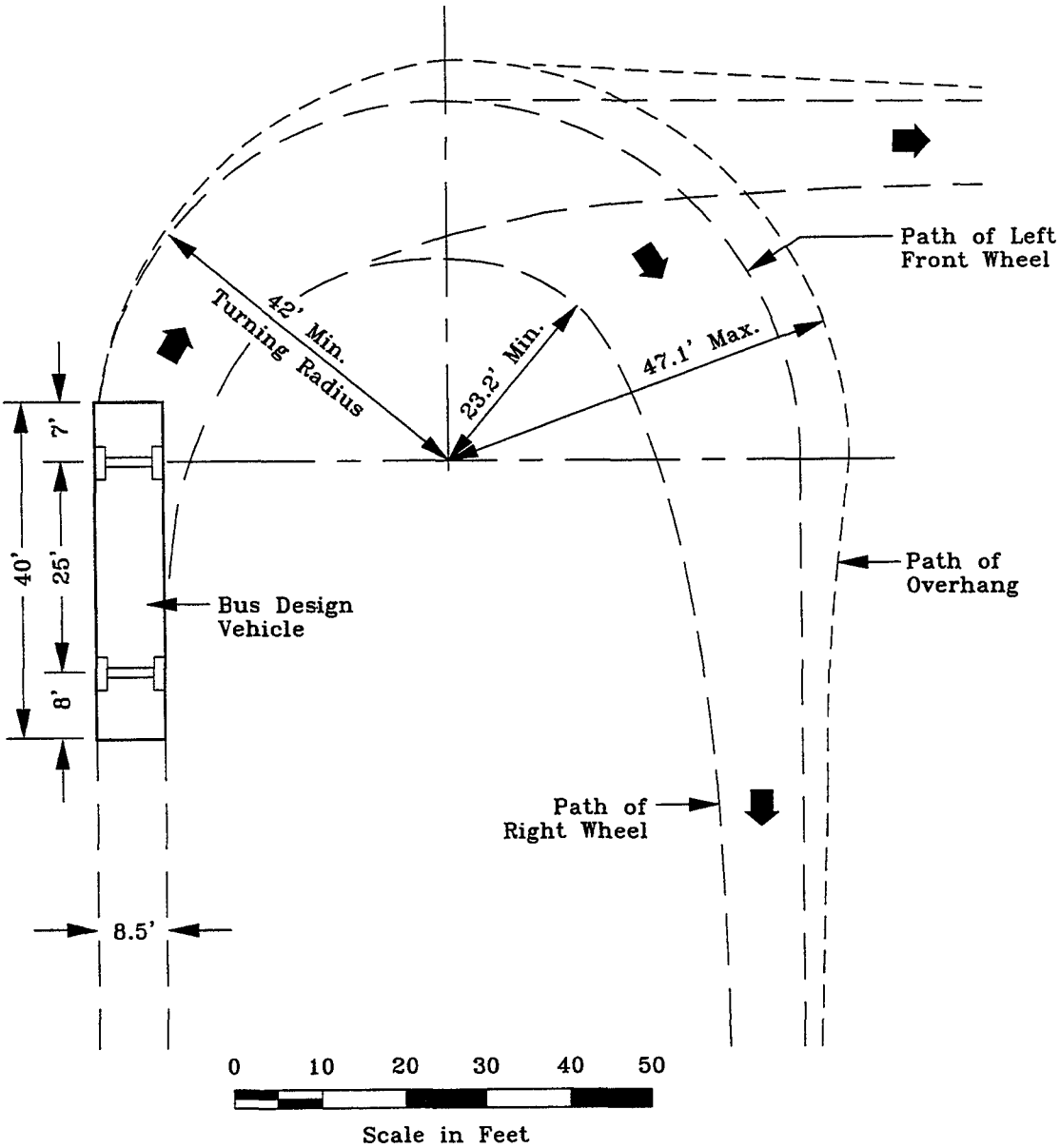


Figure 14. Design Template for Single-Unit (40 foot) Bus.

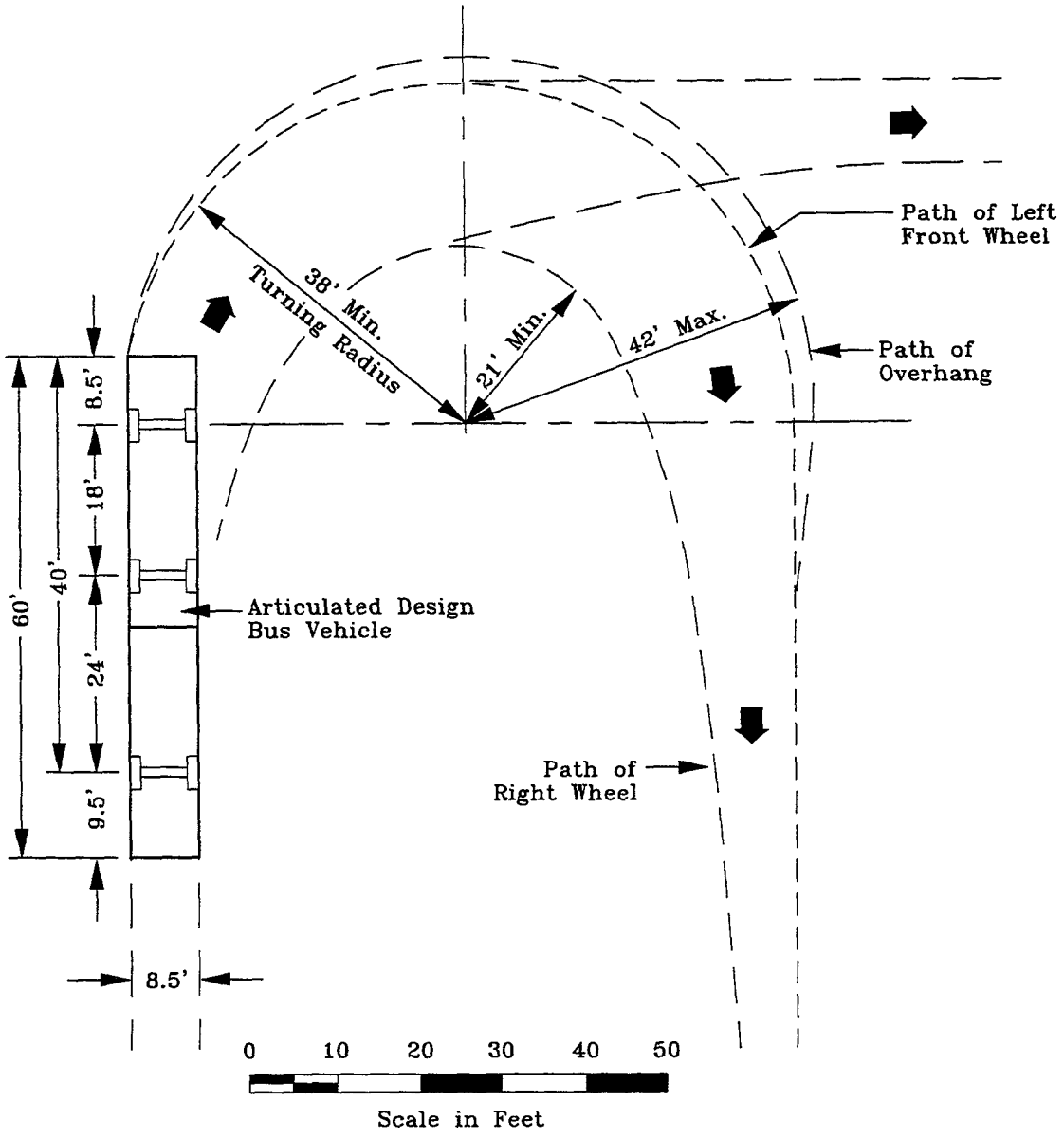


Figure 15. Design Template for Articulated (60-foot) Bus.

STREET-SIDE FACTORS

VEHICLE CHARACTERISTICS—Wheelchair Lift

Presently, the most common lifts used on buses are conventional wheelchair lifts. Figure 16 illustrates the use of a wheelchair lift. Since the wheelchair lift may be at the front or rear door, bus stop designs need to allow for either possibility. Figure 17 shows the critical dimensions for a wheelchair lift.

Low floor buses can be adjusted so the floor height is approximately 10 inches above the street level. Bus passengers in wheelchairs are then able to reach the sidewalk by using a ramp deployed from the floor of the bus. The length of the ramp typically extends 2 to 3 feet from the edge of the bus for a standard height curb.

Figure 16. Wheelchair Lift in Operation.

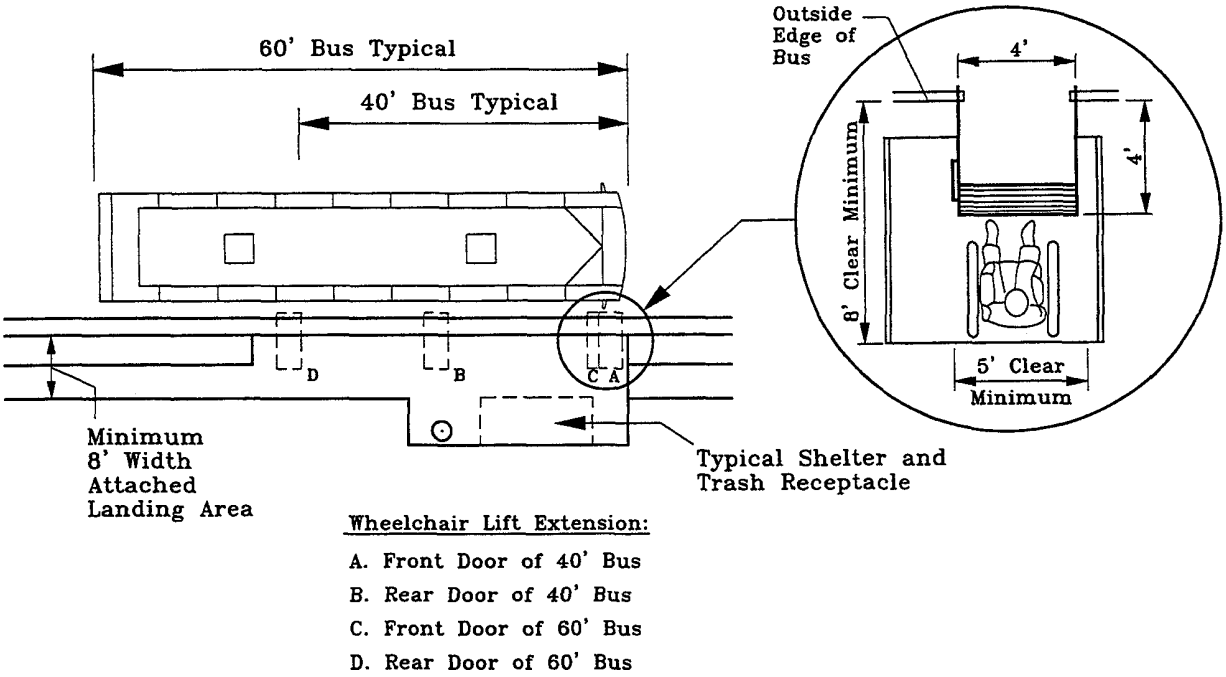


Figure 17. Wheelchair Lift Dimensions.

Several transit agencies now have on-vehicle bus storage programs. In some cases, passengers are allowed to bring their bicycles into the interior of the bus. In others, a bicycle rack is attached to the front of the bus (see Figure 18). These racks generally hold two bicycles. Busturning radius design needs to allow for the additional length of a bus with a bicycle rack attached (generally 3 feet).

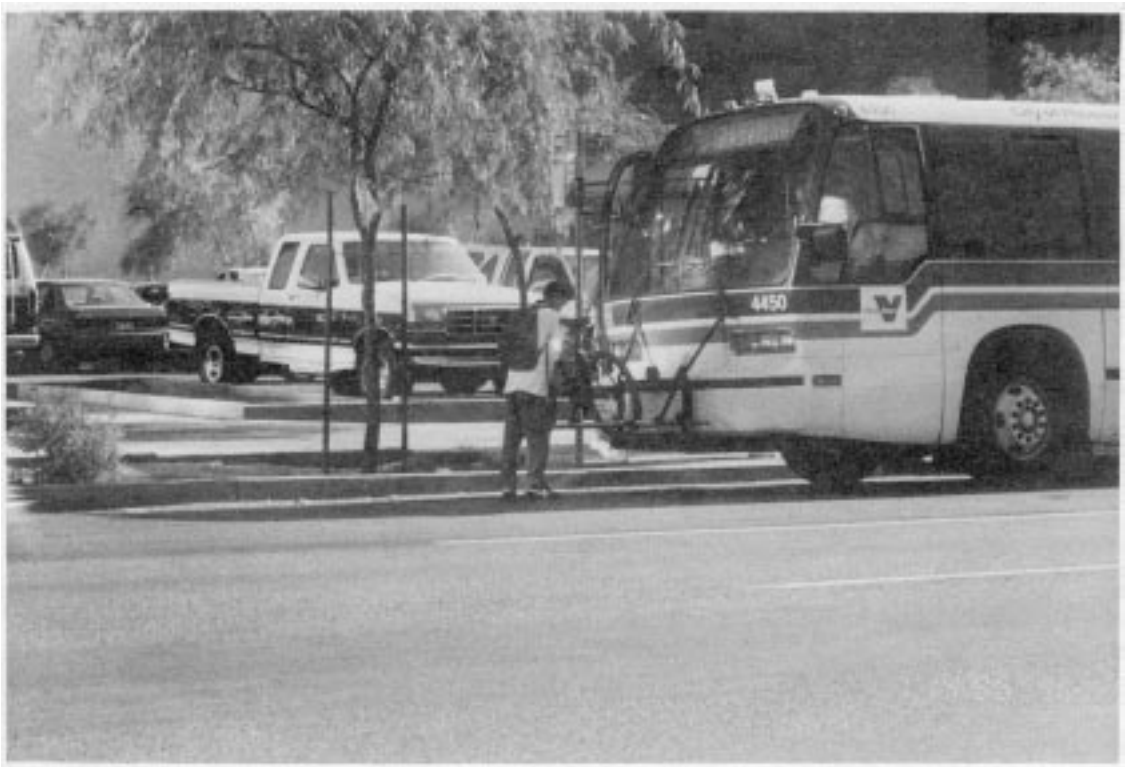


Figure 18. Front-Mounted Bike Rack in Use.

Chapter 3

STREET-SIDE FACTORS

ROADWAY AND INTERSECTION DESIGN—Roadway Design

Roadways and intersections with bus traffic and bus stops should be designed to accommodate the size, weight, and turning requirements of buses. The safety and operation of a roadway improve when these elements are incorporated into the design.

Because of their need to make frequent stops, buses generally travel in the traffic lane closest to the curb. Therefore, consideration of the following bus clearance requirements in roadway design is important.

- Overhead obstructions should be a minimum of 12 feet above the street surface;
- Obstructions should not be located within 2 feet of the edge of the street to avoid being struck by a bus mirror;
- A traffic lane used by buses should be no narrower than 12 feet in width because the maximum bus width (including mirrors) is about 10.5 feet; and.
- Desirable curb lane width (including the gutter) is 14 feet.

Selection of the roadway grade is related to topography and cut and fill material considerations. Typically, the maximum grade for 40-foot buses is between 6 and 8 percent. The recommended grade change between a street and a driveway is less than 6 percent.

An appropriate curb height for efficient passenger-service operation is between 6 and 9 inches. If curbs are too high, the bus will be prevented from moving close to it and the operations of a wheelchair lift could be negatively affected. If curbs are too low or not present, elderly persons and passengers with mobility impairments may have difficulty boarding and alighting. The effective use of low floor buses is also influenced by the height of the curb.

Roadway pavements (or shoulders, if that is where the buses stop) need to be of sufficient strength to accommodate repetitive bus axle loads of up to 25,000 pounds. Exact pavement designs will depend on site-specific soil conditions. Areas where buses start, stop, and turn are of particular concern because of the increased loads associated with these activities. Using reinforced concrete pavement pads (see Figure 19) in these areas reduces pavement failure problems that are common with asphalt. The pad should be a minimum of 11 feet wide (12 feet desirable) with a pavement section designed to accept anticipated loadings. The length of the pad should be based on the anticipated length of the bus that will use the bus stop and the number of buses that will be at the stop simultaneously.

Figure 19. Example of a Bus Pad.

The corner curb radii used at intersections (see C in Figure 20) can affect bus operations when the bus makes a right turn. Some advantages of a properly designed curb radius are as follows:

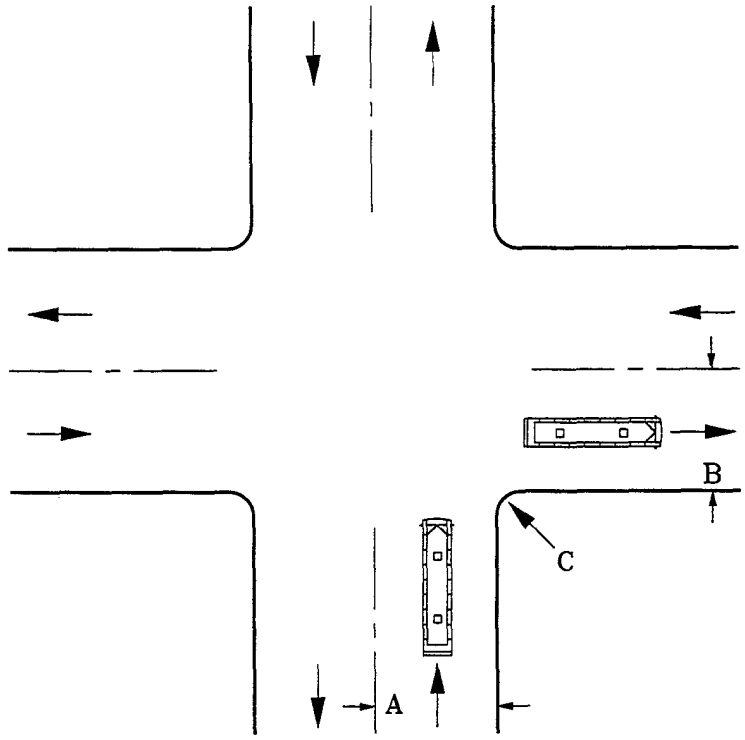
- Less bus/auto conflict at heavily used intersections (buses can make turns at higher speeds and with less encroachment);
- Higher bus operating speeds and reduced travel time; and
- Improved bus patron comfort.

A trade-off in providing a large curb radius is that the crossing distance for pedestrians is increased. This greater crossing distance increases the pedestrians' exposure to on-street vehicles and can influence how pedestrians cross an intersection, both of which are safety concerns. The additional time that a pedestrian is in the street because of larger curb radii should be considered in signal timing and median treatment decisions.

The design of corner curb radii should be based on the following elements:

- Design vehicle characteristics, including bus turning radius;
- Width and number of lanes on the intersecting street;
- Allowable bus encroachment into other traffic lanes;
- On-street parking;
- Angle of intersection;
- Operating speed and speed reductions; and
- Pedestrians.

Figure 20 shows appropriate corner radii for transit vehicles and various combinations of lane widths. This figure can be used as a starting point; the radii values should be checked with an appropriate turning radius template before being incorporated into a final design.



A Approach Width (feet)	B Entering Width (feet)	C Radii* (feet)
12 (1 lane)	12 16 20 24	50 45 40 35
16 (1 lane with 4-foot shoulder)	12 16 20 24	45 40 30 25
20 (1 lane with parking)	12 16 20 24	40 35 30 25

* Assumes no parking on cross street and minimal lane encroachment on opposing travel lanes.

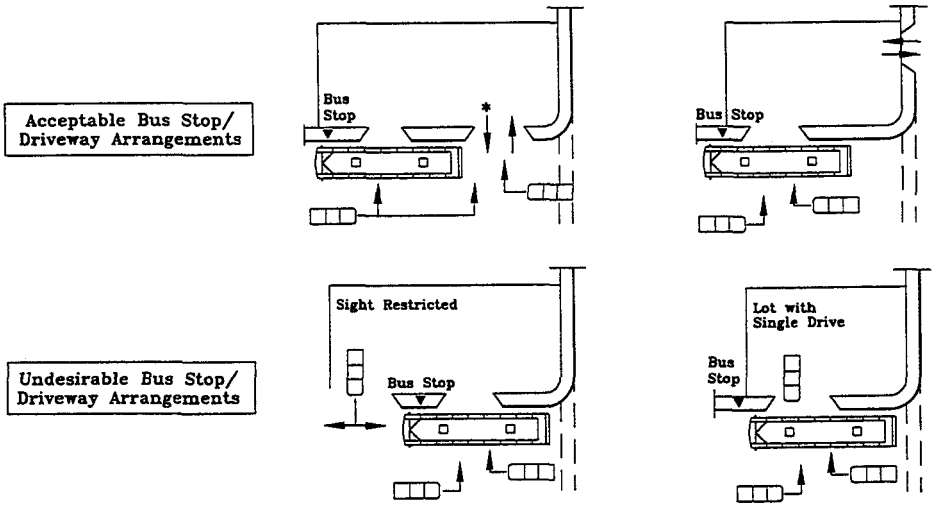
Figure 20. Recommended Corner Radii.

Bus stops are commonly located near intersections. Driveways leading to gasoline stations and other developments are also common at intersections. Ideally, bus stops should not be located close to a driveway; however, if the situation cannot be avoided:

- Attempt to keep at least one exit and entrance driveway open for vehicles accessing the development while a bus is loading or unloading passengers.
- Locate the stop to allow good visibility for vehicles leaving the development and to minimize vehicle/bus conflicts. This is best accomplished by placing the stop on the far side of the driveway.
- Locate the stop so that passengers are not be forced to wait for a bus in the middle of a driveway.
- Locate the stop so that patrons board or alight directly from the curb rather than from the driveway.

Transit agencies should work closely with local and state jurisdictions to preserve a safe loading zone for passengers from either a driveway being moved or the construction of new driveways. Cooperation in finding an alternative stop is recommended when driveways moves are unavoidable and may severely affect the bus stop. Driveways within bus bays are of special concern. Relocating a bus bay is expensive and may shift a sometimes unwanted burden to the adjacent property owner.

Figure 21 shows undesirable driveway situations where either visibility is restricted or the only drive into a parking area is blocked. The figure also shows acceptable driveway situations where visibility is enhanced and access is allowed.



While visibility is enhanced for many of the movements, sight restrictions are still present for left turning vehicles.

Figure 21. Bus Stop Locations Relative to Driveways.

Bus stops are frequently located at signalized intersections. Traffic signal design should accommodate buses and bus passengers. The following should be considered in designing traffic signal systems in new developments or upgrading/redesigning signals at existing intersections:

- Location of bus stops should be coordinated with traffic signal pole and signal head location. Bus stops should be located so that buses do not totally restrict visibility of traffic signals from other vehicles. (These problems can be effectively addressed by using far-side bus stops.)

- The use of a far-side, curbside stop at a signalized intersection can cause vehicles stopping behind the bus to queue into the intersection. A far-side bus bay is preferred at a signalized intersection.

- Since all bus passengers become pedestrians upon leaving the bus, it is important to have "WALK" and "DON'T WALK" indicators at signalized intersections at bus stops.

- When traffic-actuated signals are installed, pedestrian push buttons should also be installed to (1) activate the "WALK" and "DON'T WALK" indicators or (2) extend the signal's green indicator so that additional time needed by the pedestrian to cross the street is provided.

- Near-side stop areas are often located between the advance detectors for a traffic signal and the crosswalk. Detectors should be located at the bus stop to enable the bus to actuate the detector and the signal controller to obtain or extend the green light. Without a detector, a bus is forced to wait until other traffic approaching from the same direction actuates the signal controller.

- Timing of traffic signals should also reflect the specific needs of buses. Longer clearance intervals may be required on higher speed roadways with significant bus traffic. Vehicle passage times must provide adequate time for a bus to accelerate from the bus stop into the intersection. Intersections adjacent to railroad tracks should incorporate the need for buses to stop at railroad crossings into their timing and detection.

Chapter 3

STREET-SIDE FACTORS

ROADWAY AND INTERSECTION DESIGN—Sign Locations

Proper signs at bus stops are an important element of good transit service. Signs serve as a source of information to patrons and operators regarding the location of the bus stop and are excellent marketing tools to promote transit use. For example, letter styles, sign appearance, and color choice should be unique to the transit system so that passengers can readily identify bus stops. Doublesided signs which provide for visibility from both directions and reflectorized signs for night time visibility are preferred.

Bus stop signs should be placed at the location where people board the front door of the bus. The bus stop sign shows the area where passengers should stand while waiting for the bus. It also serves as a guide for the bus operator in positioning the vehicle at the stop. The bottom of the sign should be at least 7 feet above ground level and should not be located closer than 2 feet from the curb face. Figure 22 shows typical bus stop sign placement standards.

Transit agencies and local and/or state jurisdictions should coordinate efforts when deciding locations for bus stops and sign posts. In some cases, a shared sign post can be used to reduce the number of obstructions in high pedestrian volume locations. Bus stop signs are also commonly located on a shelter or existing pole (such as a street light). The signs should not be obstructed by trees, buildings, or other signs. Bus stop sign posts that are not protected by a guardrail or other feature should be a break-away type to minimize injuries and vehicular damage, and to facilitate replacement of the post.

Pavement markings associated with bus stops are generally installed and maintained by local authorities. The most common marking is a yellow or red painted curb at the bus stops. Stop lines and/or crosswalk markings are also desirable when the bus stop location is at an intersection.

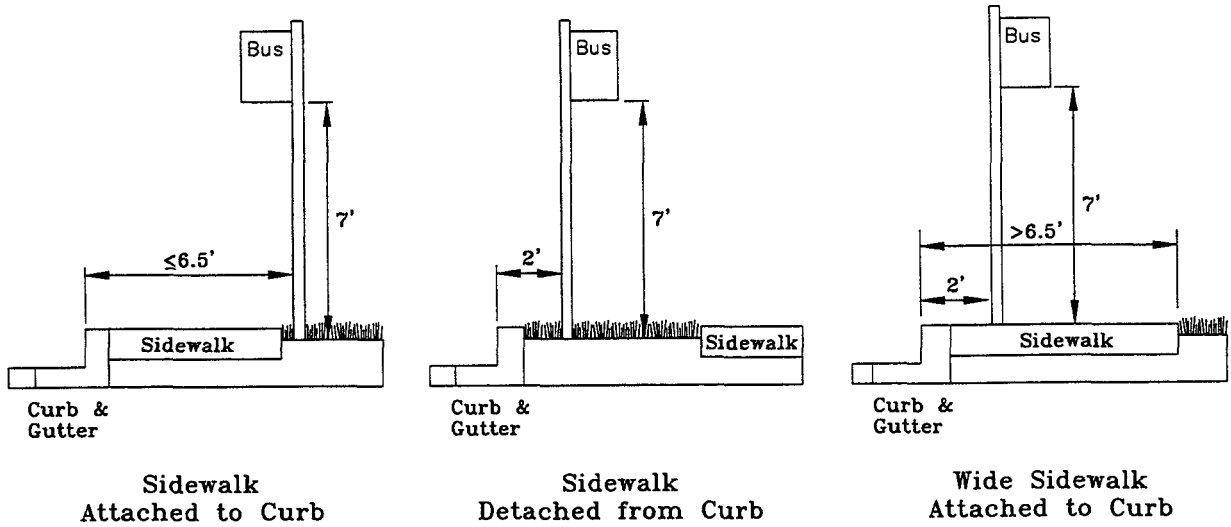
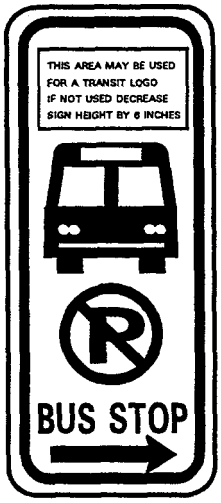


Figure 22. Guidelines for Bus Stop Sign Placement.

Traffic regulations prohibit parking, standing, or stopping at bus stops. These regulations can be established only when authorized by appropriate laws or ordinances. In general, an ordinance is needed to authorize and require a transit agency to establish bus stop locations and to designate bus stops with the appropriate signs. Another ordinance prohibits other vehicles from stopping, standing, or parking in officially designated and appropriately signed bus stops. An allowance for passenger vehicles to stop to load or unload passengers in the bus stops may be included.

The *Manual on Uniform Traffic Control Devices (MUTCD)* (maintained by the Federal Highway Administration) includes general specifications for no parking signs at bus stops and curb markings to indicate parking restrictions, as well as guidelines for the placement of the signs. Suggested signs in the *MUTCD* are shown in Figure 23. The R7-107a sign is a permissible alternative design for the R7-107 sign shown in the *MUTCD.* Other alternative designs discussed in the *Manual* may include a transit logo, an approved bus symbol, a parking prohibition, the words BUS STOP, and right-, left-, and double-headed arrows. The preferred bus symbol color is black, but other dark colors may be used. Additionally, the transit logo may be shown on the bus face in the appropriate colors instead of placing the logo separately. The reverse side of the sign may contain bus routing information.

The *MUTCD* also discusses the use of curb markings to indicate parking restrictions. At the option of local authorities, special colors (none are specified in the *MUTCD*) may be used for curb markings. When signs are not used, restrictions should be stenciled on the curb.



R7-107a
12" x 30"

R7-107
12" x 18"

Figure 23. *MUTCD* Bus Stop Signs.

Chapter 3

STREET-SIDE FACTORS

SAFETY

As with all aspects of roadway design and bus operations, an important element in the design of bus stops is safety. General safety considerations for bus stops include the following:

- The bus stop must be located so that passengers may alight and board with reasonable safety.
- The stopped bus will affect sight distance for pedestrians using the parallel and transverse crosswalks at the intersection.
- The stopped bus will also affect sight distance for parallel traffic and cross traffic. For instance, at a near-side stop, vehicular right turns are facilitated and sight distance is improved when the bus stop is set back from the crosswalk.
- The bus affects the traffic stream as it enters or leaves a stop.

A recently completed study on pedestrian accidents found that approximately 2 percent of pedestrian accidents in urban areas and 3 percent in rural areas are related to bus stops. These accidents generally involved pedestrians who stepped into the street in front of a stopped bus and were struck by vehicles moving in the adjacent lane. This situation develops when the line of sight between the pedestrian and an oncoming vehicle is blocked, or when the pedestrian simply does not look for an oncoming vehicle. This type of accident can be reduced by relocating the bus stop from the near side of an intersection to the far side, thus encouraging pedestrians to cross the street from behind the bus instead of in front of it. This makes pedestrians more visible to motorists approaching from behind the bus. Not only can far-side bus stops reduce the potential for bus stop accidents involving pedestrians, they are also less likely to obscure traffic signals, signs, and pedestrian movements at intersections, as opposed to near-side bus stops. Also, conflicts between buses and right-turning vehicles can be reduced by using far-side bus stops. Problems may occur, however, when cars illegally park in far-side bus stops preventing buses from completely clearing the cross street.

Along with the minimum desirable curb length, the condition of the curb lane and the curb height can influence the safety and efficiency of bus-passenger operation. When poor pavement conditions exist in the curb lane, bus drivers often avoid it and stop the buses away from the curb. Boardings and alighting operations away from the curb are more hazardous for riders than curb operations, especially for elderly persons and passengers with disabilities during inclement weather. The additional hazard appears to result from the increased height between the ground and the first step of the bus and from moving vehicles (such as bicycles) between the curb and the bus.

Lighting is important for safety. A brightly lit bus stop makes it easier for the transit operator to observe waiting passengers and allows motorists to see boarding and alighting pedestrians. Because the step well is the most hazardous area on a transit vehicle for accidents, a brightly lit well will assist boarding and alighting passengers as they judge distances and locations of steps and curbs. Auxiliary lighting in the step well is required on new buses, but it will be years before this feature is universal.

The bus stop should be located either before the turn lane (for through routes) or at the far side of the intersection in areas that have a dedicated right-hand turn lane. Transit agencies should work closely with local and state jurisdictions wherever traffic improvements affect the safety of a bus stop. The addition of turn lanes will often require advance planning for incorporating transit accommodations as part of the highway project and/or for relocating the bus stop to an acceptable location.

Chapter 3

STREET-SIDE FACTORS

STREET-SIDE PLACEMENT CHECKLIST

Several items should be considered when designing and locating a bus stop on a roadway. The following checklist of street-side items should be reviewed with each design because it brings together related issues that can have a significant impact on the safe operations of the bus stop.

- **Standardization:** One of the most critical factors in the street-side design and placement of a bus stop involves standardization or consistency. Standardization is desirable because it results in less confusion for bus operators, passengers, and motorists. Consistency in design, however, can be difficult to achieve since traffic, parking loss, turning volume, community preference, and political concerns can influence the decisions.

- **Periodic Review:** A periodic review of bus stop conditions (both street side and curb side) is recommended to ensure the safety of bus passengers. This will encourage the timely reporting of items such as missing bus stop signs and poor pavement.

- **Near-Side/Far-Side/Midblock Placement:** Each type of placement has advantages and disadvantages. In general, each bus stop location should be evaluated individually to decide the best placement for the stop.

- **Visibility:** Bus stops should be easy to see. If the bus stop is obscured by nearby trees, poles, or buildings, the bus operator may have difficulty locating the stop. More importantly, however, motorists and bicyclists may not know of its existence and will be unable to take necessary precaution when approaching and passing the stop. In addition, visibility to pedestrians crossing a street is also an important consideration in areas that permit "right turns on red."

- **Bicycle Lanes and Thoroughfares:** When a bike lane and a bus stop are both present, the operators need to be able see cyclists in both directions while approaching the stop. Sufficient sight distance for cyclists to stop safely upon encountering a stopped bus is also needed.

- **Traffic Signal and Signs:** Bus stops should be located so that buses do not restrict visibility of traffic signals and signs from other vehicles. Because all bus passengers become pedestrians upon leaving the bus, pedestrian signal indicators should be considered at nearby signalized intersections.

STREET-SIDE PLACEMENT CHECKLIST

- ☐ **Roadway Alignment:** Horizontal and vertical roadway curvature reduces sight distance for bus operations, motorists, bicyclists, and pedestrians. Additionally, bus stops located on curves make it difficult for the bus operator to stop the bus parallel to the curb and safely return to the driving lane. Where possible, bus stops should be located on sections of relatively straight and flat roadway. Trees and poles should not obstruct the visibility of the bus operator for cross traffic and passenger and pedestrian movement.

- ☐ **Driveways:** Avoid locating bus stops close to a driveway. If placing a bus stop close to a driveway is unavoidable (for example, to lessen the loss of parking in a commercial area), keep at least one driveway open to vehicles accessing the adjacent development while a bus is loading or unloading passengers. Also, locate bus stops to allow full visibility for vehicles leaving an adjacent development and to minimize vehicle/bus conflicts. Placing bus stops on the far side of driveways will minimize conflicts; however, sight distance for left-turning vehicles from the driveway will still be a concern.

- ☐ **Location of Pedestrian Crosswalks:** A minimum clearance distance of 5 feet between a pedestrian crosswalk and the front or rear of a bus at a bus stop is desirable.

- ☐ **Location of the Curb:** Where possible, locate stops where a standard curb height of 6 inches exists. Bus steps are designed with the assumption that the curb is the first step. It is more difficult for elderly persons and passengers with mobility impairments to board and alight from the bus if the curb is absent or damaged.

- ☐ **Street Grades:** Where possible, bus stops should not be located on an upgrade in a residential area, since the bus engine noise created when the vehicle accelerates from a stop will bother area residents. Placing bus stops on steep grades should be avoided if slippery winter conditions prevail.

- ☐ **Road Surface Conditions:** Since alighting passengers generally move from their seats when the bus decelerates on approach to a bus stop, do not locate a bus stop where the roadway is in poor condition such as areas with broken pavement, potholes, or ruts or where a storm drain is located. The resultant motion of the bus in such a situation may cause bus passengers to fall and injure themselves. Boarding and standing passengers are also susceptible to falls or injuries where poor pavement conditions or low drainage basins exist.